TWO-DIMENSIONAL KINEMATICS OF A BAR AND CENTRAL DISK IN NGC 5448

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Abstract We analyse SAURON kinematic maps of the inner kpc of the early-type (Sa) barred spiral galaxy NGC 5448. The observed morphology and kinematics of the emission-line gas is patchy and perturbed, indicating clear departures from circular motion. The kinematics of the stars is more regular, and displays a small inner disk-like system embedded in a large-scale rotating structure. We focus on the [O III] gas, and use a harmonic decomposition formalism to analyse the gas velocity field. The higher-order harmonic terms and the main kinematic features of the observed data are consistent with an analytically constructed simple bar model, which is derived using linear theory. Our study illustrates how the harmonic decomposition formalism can be used as a powerful tool to quantify non-circular motions in observed gas velocity fields.

1. Introduction

Line-of-sight velocity distributions are efficient probes of the dynamical structure of galaxies, and can be used to derive the mass distribution, intrinsic shape and the motions of stars and gas. Non-axisymmetric components such as bars, or external triggers, can lead to significant galaxy evolution via, e.g., redistribution of the angular momentum, triggering of star formation, or building of a central mass concentration (e.g., Shloshman et al. 1989; Knapen et al. 2000). Much can be learned about these processes by simultaneously studying both the stellar and gas dynamics of nearby galaxies by means of integral-field spectroscopy. Here we summarize such a study for the spiral galaxy NGC 5448, which was observed with SAURON as part of a representative survey of 72 nearby early-type galaxies (de Zeeuw et al. 2002; Falcón–Barroso et al. 2005). A more comprehensive report can be found in Fathi et al. (2005).

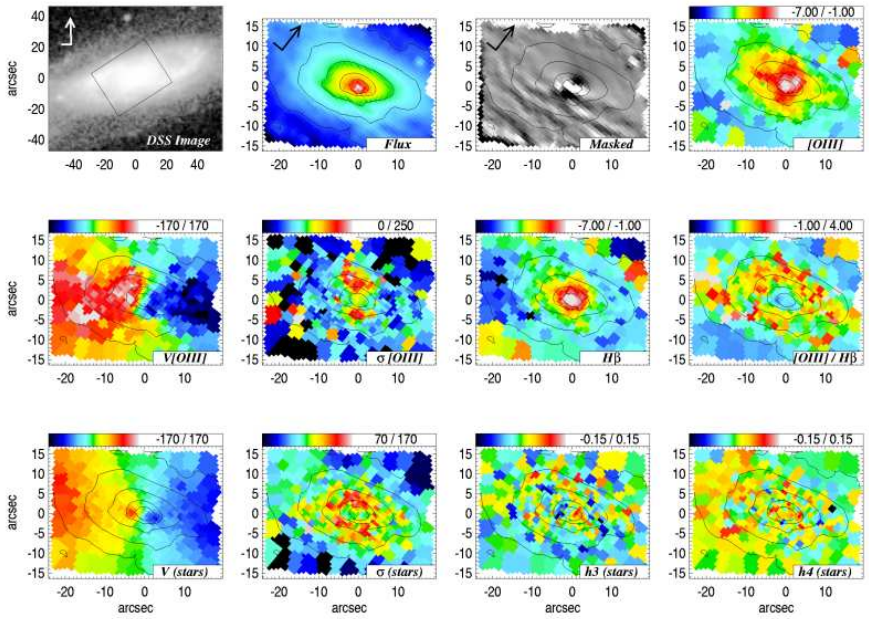

Figure 1. Top Left: Digitised Sky Survey image with SAURON footprint and north-east orientation arrow. All other panels show the SAURON data with the same orientation and overplotted contours in magnitude steps of 0.25. Two-dimensional Voronoi binning has been applied to all our maps, as described in Falcón–Barroso et al. (2005). The titles are indicated at the bottom right corner of each panel with plotting ranges according to the top color bar. All velocities and velocity dispersions are given in km s^{-1}.

2. Data

We observed NGC 5448 with SAURON on April 14th 2004. Detailed specifications for the instrument, reduction procedure, and the data preparation procedure can be found in Bacon et al. (2001); Emsellem et al. (2004); Sarzi et al. (2005). The SAURON flux map in Fig. 1 displays a smooth stellar distribution and the presence of prominent dust lanes to the south of the nucleus. The stellar kinematics shows a global disk-like rotation with a smaller inner stellar disk within the central 7″ radius. Along the strong dust lanes, the gas shows a patchy distribution, with an asymmetric elongation of [O III] gas towards the east as well as the galactic poles. The gas velocity map clearly shows a prominent 'S'-shaped zero-velocity curve with sharp edges indicating very strong non-circular gas motions.

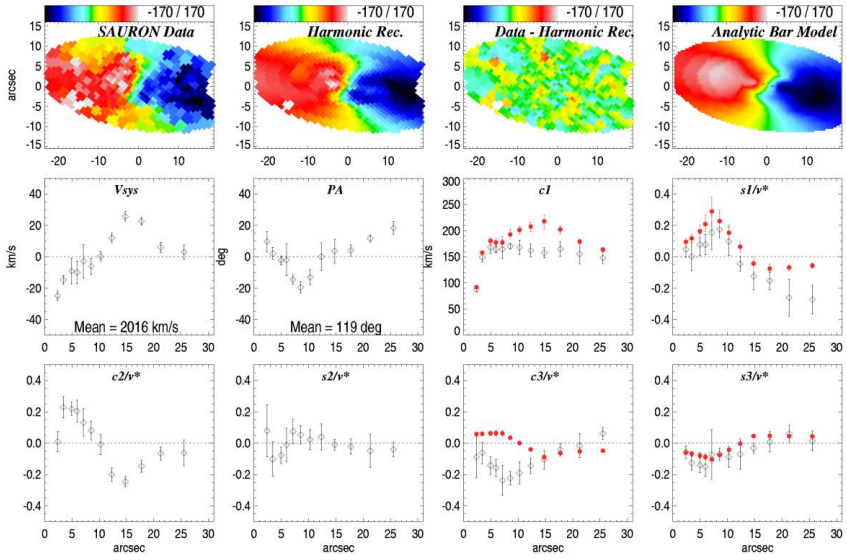

Figure 2. Top row, from left to right: observed SAURON gas velocity field of NGC 5448; the harmonic reconstruction of the SAURON gas velocity field; residual field; and the analytic bar model, which reproduces best the main kinematic features of the observed gas velocity field (in km s^{-1}). Middle and bottom row: the tilted-ring and harmonic parameters as a function of outer radius of each ring, and $v^* = c_1 \sin i$. The over-plotted red filled circles are the analytically calculated first and third harmonic terms for the bar model, with the 3σ (99.7%) confidence level error bars. The orientation of the maps is the same as in Fig. 1.

3. Analysis and Results

In order to study the gas velocity field, we apply the tilted-ring decomposition combined with the harmonic expansion formalism from Schoenmakers et al. (1997). This formalism allows us to extract the gaseous kinematic information such as the rotation curve, kinematic position angle variation, and higher harmonic terms. Wong et al. (2004) derived the higher-order harmonics for an axisymmetric potential with an $m = 2$ bar perturbation. This bar model depends on a set of parameters describing the potential, as well as the viewing angle. We construct libraries of models with different input parameters, and find that we can describe our observed velocity field with the bar model shown in Fig. 2. Thus, the radial motions of the gas are associated with that of the large-scale bar (see Fathi et al. 2005 for a detailed discussion).

NGC 5448 exhibits clear signatures of the presence of other components than a single bar, which affect the observed velocity field. Inspecting the photometry and the central parts of the gaseous and stellar velocity field, we find signatures of a central stellar disk embedded in the larger disk (see Fig. 3). We

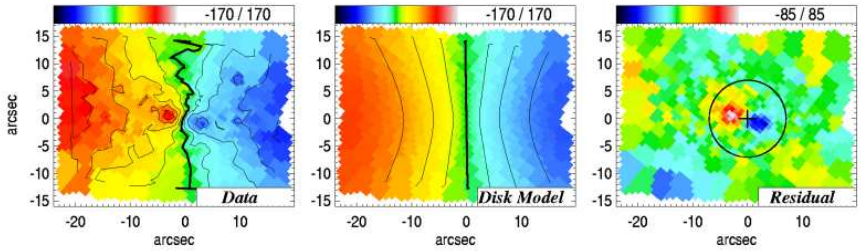

Figure 3. A thin isothermal disk model for the stellar velocity field of NGC 5448. The circle marks the 7″ region within which we find a disk-like structure. All maps are given in km s^{-1}.

approximate the stellar velocity field with an exponential thin disk to emphasize the kinematic signatures of the central disk. Fig. 3 illustrates our simple inclined disk model, after subtraction of which we find that the inner stellar disk-like component rotates faster than the outer disk. Fitting also an exponential disk to the region interior to the 7″ radius, we find that the central disk-like structure is misaligned with respect to the outer disk by $\sim 13^{\circ}$. The stellar kinematic maps show that the central disk rotates faster than the main disk, and our observed gas distribution and kinematics indicate that this central disk also hosts gas which rotates faster than its stellar counterpart. It is known that bars are efficient in transferring mass towards the inner regions of their host galaxies. The centrally concentrated matter may be able to form a secondary bar or a central disk. Our analysis shows that the non-circular gas kinematics in NGC 5448 could be driven by the large-scale bar. The central disk could then have been formed as a result of the gas accumulation at the centre.

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